SCIENCE

VOL. 77 | FRIDAY, JUNE 16, 1933 | No. 2007

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SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal
Lancaster, Pa. Garrison, N. Y.
Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

THE RÔLE OF ANALYSIS IN SCIENTIFIC INVESTIGATION[1]

By Professor DOUGLAS JOHNSON
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CUSTOM decrees that the chairman of your section should, at the interval of a year following his presidency, deliver before you an appropriate address. It has seemed to me that I could best command your interest in some field of discussion where every one of us, geographer and geologist alike, has had experience. So I have selected the broad field connoted by the highly inclusive term, "scientific investigation"; and I would direct your attention, not to any particular results of such investigation, but to a concrete problem of method which I suppose must concern every scientific worker. This problem can briefly be stated as follows: What is the precise rôle of analysis in a properly conceived and successfully executed scientific investigation?

It goes without saying that I am not competent to speak of methods of research in chemistry and physics, where experiment plays a far larger rôle than in geology and geography. So also the biologist, the astronomer and investigators in other fields must speak for themselves. For this reason the title of my address may seem unduly ambitious. Yet I prefer the broader, more inclusive term "scientific investigation" to the more restricted if more accurate "geologic and geographic investigation," because it seems to me probable that some of the principles here discussed may find application beyond the limits of my particular field.

It is a pleasure to express here my indebtedness to several of my Columbia colleagues, Robert S. Woodworth, professor of psychology; Adam Leroy Jones, associate professor of philosophy; Sam F. Trelease,

[1] Abbreviated form of address as retiring vice-president and chairman of Section E—American Association for the Advancement of Science, delivered at Atlantic City, on December 27, 1932. The address will be published in amplified form, with fuller illustration from shore line studies, in the *Bulletin of the Geological Society of America.*

professor of botany; and George B. Pegram, professor of physics; also to Professor William Morris Davis. All these were good enough to read the address in manuscript form and give me the benefit of helpful criticisms.

The dictionaries tell us that analysis is the process of separating a thing or a concept into its constituent parts, in order to arrive at the essential or ultimate elements, causes or principles; that it is the tracing of things back to their sources; and that it is designed to clarify and test knowledge. The chemist analyzes a complex substance to determine its precise composition. For the purposes of our discussion I would define scientific analysis as "the process of separating observations, arguments and conclusions into their constituent parts, tracing each part back to its source and testing its validity, for the purpose of clarifying and perfecting knowledge."

I am persuaded we can pursue our discussion most easily if I illustrate my observations, so far as feasible, by reference to some concrete example. For sake of simplicity I shall select a common phenomenon found on the rocky shores of many lands, and in tracing the part played by analysis at each stage of a comprehensive scientific investigation, shall illustrate my points freely by referring to the study of this phenomenon, the origin of which is still a subject of dispute. Those who follow this discussion should not attach undue importance to the particular example selected for illustrative purposes, nor to the statements made concerning it. I have purposely selected a debatable matter, the study of which is not yet completed. Our concern here is not with the origin of the phenomenon, but with the method of investigating its origin.

Along the rocky shores bordering the sea are found nearly horizontal platforms or benches from a few feet to a few hundred feet in width, cut in solid rock. At their seaward margins these benches terminate in relatively abrupt slopes which descend toward or even into the water. From their inner or landward margins rise steep slopes or rocky cliffs. In elevation the benches range from 1 or 2 feet above ordinary high tide indefinitely upward, often several hundred feet above the same datum plane.

The combination of bench and cliff bordering the sea might arouse no significant reaction in the mind of the ordinary observer. But such a combination instantly excites the brain of the geomorphologist to activity. Memory recalls text book diagrams, explanatory titles under photographs of similar features, discussions of the origin of such features in geological and geographical treatises, perhaps earlier field examination of such forms. Rapidly the mind compares the forms, the situations, the mutual relations of the assembled features in the various cases called before it by observation and memory, and before the observer is conscious of the process he has leaped to an inductive inference: that both bench and cliff were cut into the margins of the land by wave erosion. In this case the inductive inference involves an explanation. But it is only a partial explanation. If the bench is wave-carved, why is it exposed to view above the level of the sea? The mind rushes on: Perhaps the land has been raised since the bench was carved. Perhaps the sea level has dropped.

The observer must now be on his guard against a dangerous tendency of the human intellect—the tendency to accept as valid a plausible explanation, and then to look for facts in support of that explanation. He must deliberately repress the tendency toward premature conclusions, and begin the task of gathering all the facts upon which alone can a satisfactory explanation be based. As already stated, we are not primarily concerned with the course of his particular investigation of these interesting forms, nor with the conclusions he may reach respecting their origin. But we shall draw freely upon this imaginary hypothetical study, to illustrate the uses of analysis in scientific research.

I. Analysis in the Stage of Observation

The initial stage in scientific investigation is normally that of observation. The first employment of this mental process may be made incidentally, perhaps almost passively. But once the investigator realizes that the observed facts present a problem, for the solution of which additional facts are desirable, he becomes an active inquirer, seeking to discover all facts bearing on the problem. He observes as widely and as accurately as possible, the observed facts being automatically recorded in his memory; but also, since the memory is notoriously fallible, deliberately recorded in his note book if he be a prudent investigator.

Since we are here concerned merely with the recording of external facts observed by the eye, it might appear that analysis has no rôle to play in this initial stage of an investigation. But let us dissect the matter and scrutinize its parts, first turning our attention to the material facts which are the object of observation. Can the analytical powers of the mind be brought to bear upon the facts themselves in such manner as to aid the investigator?

Let our hypothetical student of coastal benches answer. Having observed one such bench, and had his curiosity aroused to investigate, he begins his search for other examples. Very soon he is confronted by the necessity of discriminating coastal benches of the type described above from other forms similar in some respects yet different in others. He needs a name by which to designate the type forming

the particular object of inquiry, and tentatively calls them elevated marine benches or simply "marine benches," because of their resemblance to submarine benches formed by wave abrasion and because of their apparent marine origin.

The question then arises: What constitutes a marine bench in the sense in which he is using the term? Is it any nearly level surface in the vicinity of the shore, terminated seaward by an abrupt descent, and landward by cliffs which rise steeply to higher levels? This combination of slopes appears repeatedly in nature, as the product of a variety of causes. The non-critical investigator, who welcomes every shelf and scarp facing the sea as one more link in the chain of facts he seeks to explain, is almost sure to accumulate, without knowing it, an assortment of unrelated observations, many of them irrelevant to his problem. His investigation is seriously compromised from its very beginning. How can he explain the origin and history of elevated marine benches if he unwittingly bases his reasoning on a confused mixture of wave-carved surfaces, benches due to differential weathering, rock terraces cut by a river before drowning brought in the sea, notches cut by a glacial stream flowing between waning continental ice and the sloping hillside, and terraces due to landslides, faulting or monoclinal warping. As all these features are found in the immediate vicinity of the shore in different places, and as all of them have repeatedly been ascribed to wave erosion, it is clear that the field data must in the first instance be subjected to rigid scrutiny.

The facts can not be lumped. They must be separated into their constituent parts, and each part tested as to its relevancy to the problem under investigation.

Thus far we have discussed the necessity of analyzing the things observed. But the investigator must probe more deeply than that. He must analyze the observational process itself. Does he really see what he thinks he sees? Not unless he is constantly on guard against the well known dangers to which observation is subject. Chief among these, perhaps, is the tendency to include inference with fact, to confuse theory with observation. The observer thinks he sees a bench cut in granite, when in fact all he really observes is a few scattered outcrops of granite protruding through the soil; from these he infers, and perhaps erroneously, that the vastly larger invisible mass is likewise granite. Another investigator may report that he saw a wave-carved bench which did not bevel the rock layers. All he really saw was a shelf or bench parallel to the rock layers. He inferred it was wave-carved, when in fact it may have been produced by differential weathering of weaker beds overlying a more resistant layer.

Another danger to which observation is subject is that of ocular deception. This danger looms large when one is looking for certain specific forms in the landscape. The power of suggestion is greater than many realize, and one looking for marine benches is in danger of finding them in faint undulations or irregularities of the terrain which under other circumstances would not impress him as significant. If he is looking for benches which he expects to be horizontal, the inclined position of something he mistakes for such a bench may quite escape his eye, even when the inclination is so marked as to be quite obvious to another who is without preconceptions as to what should be observed.

Incompleteness of observation is another common danger. The eye tends to pick from the landscape that which seems to it for the moment significant, and fails to note much that later stages of the study may show to be vitally important. Even where the initial observation is fairly complete, the benefits which should be derived from it may be lost through failure to record permanently in memory and in note book all the facts observed.

No one is wholly free from the dangers of defective observation. But one who acquires the habit of analyzing his observational powers and processes is less exposed to these dangers than are those who give no conscious attention to this initial step of a scientific investigation. In research, as in other things, to be forewarned is to be forearmed; and the investigator who is conscious of the dangers inevitably associated with the observational process will be on his guard against those dangers.

II. Analysis in the Stage of Classification

Is there any need for employing analysis in the second stage of an investigation, the stage of classification? Let us note first that the analysis involved in stage one led to a sort of rudimentary classification, the separation of observed facts into those which were relevant and those of doubtful relevancy. We at once suspect that analysis must likewise be involved in any further effective classification of the facts of observation surviving the analysis of stage one.

The investigator is not content merely to exclude from consideration every doubtful bit of data. For example, our hypothetical student does not rest when he has excluded from his study every topographic form which does not certainly belong in the group of elevated marine benches. He raises the question as to whether all these benches need necessarily have had the same history. For he takes cognizance of the fact that if the benches were carved at different times, and some of them were affected by events, such as continental uplift, which did not affect the others, a serious difficulty may be introduced into the attempt to explain their history. The investigation, to be suc-

cessful, must deal with a group of facts which are comparable. A simple hypothesis competent to explain benches five feet above high tide may conceivably be quite incompetent to explain benches fifteen feet above high tide.

III. Analysis in the Stage of Generalization

Classification paves the way to the third stage of investigation, in which generalization occurs. Thus in our hypothetical study of marine benches, it is only when classification has been effected that the investigator can make significant generalizations; such, for example, as that in one group the benches have a narrow range in altitude, are always close to the sea, present no evidence of weathering of the rock surfaces, and are free from debris; that in a second group the benches have higher altitudes but equally narrow range in altitude, present evidence of moderate weathering and have small quantities of debris near their inner margins; while in a third group the benches are still higher, vary extensively in altitude and have surfaces which are deeply weathered and prevailingly covered with debris.

We have now to inquire whether the analytical faculties of the investigator can serve any useful purpose in the stage of generalization. Let us first note that the empirical generalizations stated above, free from any explanatory element, had their roots in the careful analysis that made effective classification possible. But it is when inducing generalizations which involve more or less of explanation that the analytical process can render greatest service. Such generalizations, like those free from explanation, must be rooted in the facts and represent a normal outgrowth of them. They must be legitimate inferences induced from the facts themselves. As we shall see in a later section, the investigator may formulate conceptions involving explanation which are not an immediate normal outgrowth of the facts, but the products of invention. As these two types of explanation, the induced and the invented, have somewhat different standing before the court of the intellect, it is important that they be not confused. It is in making this discrimination that the investigator must again employ his analytical powers. The nature of the facts, the nature of their distribution, their relationships, and other pertinent elements must critically be examined, to the end that only legitimate inferences may be induced from them.

For example, the first two groups of classified facts described above, in both of which uniformity of altitude above sea level is a characteristic of the benches, may properly give rise to the generalization that after the benches were carved the sea level dropped. Uniformity of bench altitude suggests this as a legitimate inference involving explanation. But no such generalization may be based on the third group of facts, in which great variation in elevation is an outstanding characteristic of the benches. Such heterogeneity in elevation does not suggest either uniform drop of sea level or systematic differential uplift of the land. Perhaps the facts can be explained on the basis of one or the other of these explanations, or on both combined; but if so the explanations must be deliberately invented and applied to the facts. They are not normal outgrowths of the facts.

IV. Analysis in the Stage of Invention

In the fourth stage of our hypothetical investigation the inquirer takes the classified facts and the generalizations concerning their nature, and uses them as a basis for invention of as many explanations of the facts as may be possible. It is here that "the scientific use of the imagination," as Tyndall has happily phrased it, comes most prominently into play. The invention may be deliberate, the result of conscious effort. Often it springs unexpectedly into consciousness, the result of a mind well equipped with pertinent knowledge repeatedly "mulling over" the facts in variable combinations. If others have anticipated our inquirer in the inventive process, as is usually true in greater or less measure, he welcomes every idea of alien origin which offers a possible explanation of the facts, and accords it just as hospitable treatment as those born of his own intellect. If the generalizations of stage three involved explanation of the facts, the investigator seeks additional and independent explanations. Where generalization involved but partial explanation, or merely paved the way for an explanation, the investigator employs his inventive powers to complete the unfinished task; and then moves forward to the invention of alternative explanations.

The process of invention is not fully understood. It resembles induction to the extent that the mind starts with concrete facts, and from them passes to conceptions of broad application which take the form of tentative explanations of the facts. But the mind has far greater liberty in the stage of invention than in the preceding stage of generalization. The relation to facts is here less close. A proper generalization, being an outgrowth of the facts, must have its roots well grounded in them. An invention may spring from "thin air," the rarefied atmosphere of more abstract reasoning. The stimulus to invention comes from the facts, and the thing invented must not palpably be contradicted by the facts; but it need not be a normal outgrowth of the facts. Thus, the conception of a uniform drop of sea level was, as we have seen, wholly improper as a generalization based on the third group of facts, relating to marine benches of widely varying altitude, since nothing in

this group of facts could rightly give birth to such a conception. But the same conception may properly be invented, "out of thin air," and offered as a possible explanation of the facts in that group, since none of them necessarily contradicts the explanation.

We have noted the greater liberty enjoyed by the mind in the stage of invention. But it is not wholly free. Since the explanations induced in stage three and those invented in stage four are to serve as working hypotheses in the deductive operations of stage five, they must conform to certain fundamental requirements governing the formulation of hypotheses. In the first place, it is essential that the tentative explanations should be so precisely molded that specific deductions may be derived from them. If an explanation is so vague in its inherent nature, or so unskilfully molded in its formulation, that specific deductions subject to empirical verification or refutation can not be based upon it, then it can never serve as a working hypothesis. A hypothesis with which one can not work is not a working hypothesis.

Again, the explanation as formulated must be possible, for explanations clearly contradicted by well-established natural laws waste time and energy without advancing the investigator toward the true goal of his researches. On the other hand, it is manifestly dangerous to exclude explanations which merely appear incredible or absurd because they run counter to established opinions. Many a door to truth has thus prematurely been closed and long remained closed. The hypothesis of continental glaciation seemed incredible in 1840, as did the hypothesis of evolution in 1860.

How then shall the inventive mind properly mold its hypotheses and distinguish between explanations which appear plausible but are really unsound and those which immediately provoke distrust yet merit hospitable consideration? It seems to me that here the analytical process offers us an instrument of incalculable value. Let us dissect each tentative explanation into its component elements, trace each element back to the assumptions and inferences which lie hidden behind it and test the reasonableness of the whole by testing the validity of each part.

V. Analysis in the Stage of Verification and Elimination

On entering the fifth stage of the investigation our hypothetical inquirer possesses, let us suppose, some half dozen tentative explanations which have survived the analytical processes applied in the preceding stage. He now treats each of these in turn as a working hypothesis, and reversing the mental processes employed in the third stage, endeavors by deductive reasoning to determine as precisely as possible just what features should characterize the shore platforms in case the particular hypothesis for the moment under scrutiny be the true explanation of these forms. His object is to verify, so far as possible, the competence of some hypotheses and to eliminate others which critical tests show to be manifestly incompetent.

He secures the required tests by an appeal to facts. After deducing the reasonable consequences of a working hypothesis, he confronts these by such facts as are already in his possession, drawing upon memory, upon his field notes and upon the published observations of others. If the consequences logically deduced from the hypothesis are in accord with the facts, he accepts this as verification of the competence of the hypothesis to explain the facts already in hand. Where deduced consequences find no counterpart in observed facts, he feels justified in eliminating the hypothesis from further consideration.

To what extent, if any, can analysis serve the investigator in this stage of verification and elimination? Since effective use of the deductive process depends upon one's ability to make logically correct deductions, it is expedient that the investigator should subject his own mental processes to careful scrutiny. There are fallacies in reasoning which must be avoided. These are treated in works on logic and need not be discussed here. But some study of logic will direct conscious attention to one's mental habits, and help to secure the precision and completeness requisite for careful deduction.

The investigator must realize that if his deductions are false, it matters little whether observed facts correspond to them or not. The conclusions are in any case invalidated, and he may either reject a perfectly valid hypothesis or embrace one which is invalid, on the basis of false reasoning. Saftey lies only in analysis. Deductions, like inductions, must be separated into their component parts, and each part scrutinized and its validity tested. Let us illustrate what this involves by turning once again to the problem of the shore platforms.

Let us suppose that our investigator has accepted as one working hypothesis the tentative explanation of storm-wave erosion under present conditions of land and sea level. From this hypothesis he deduces certain expectable consequences, among which let us consider only one. If the platforms are the product of storm waves operating at the present time, he reasons, then there should be found upon their surfaces rock debris constituting the cutting tools with which waves accomplish their erosive work. Turning to his record of field observations, he finds that many of the platforms are remarkably free from debris. Indeed, their outer edges commonly drop abruptly into moderately deep water, so that it is difficult to see how much debris could be cast upon the platforms or maintained there. The facts in hand conspicuously

fail to match the expectations deduced from the hypothesis, so our investigator rejects the hypothesis of storm-wave erosion as incompetent. In doing so, he rejects a perfectly valid hypothesis solely because he failed to examine his deductions critically before using them as tests of the competence of the hypothesis.

Let us suppose, however, that our investigator was so fully convinced of the value of analysis as an instrument of research that he would neither accept nor reject a hypothesis until he had subjected each deduction derived from it, and each test of its correspondence with the facts, to such rigid scrutiny as he was able to make. Under these circumstances he would first have examined the deduction relating to the expected presence of wave-cutting tools on the platforms. He would have asked: Upon what does the deduction rest? Evidently upon the assumption that waves of water unarmed with debris can not effectively erode the coast. And on what, in turn, does this assumption rest? Current geologic opinion may run this way, and geologic text books may assert that waves without cutting tools are feeble. But current opinion and the text books have often proved fallible guides. So our investigator would have gone back to the sources on which both opinion and textbook should be based; the actual recorded evidence as to the nature and causes of damage accomplished by waves. Here he would have found much information concerning havoc wrought by waves under conditions which seem clearly to preclude the effective intervention of debris. The terrific impact of the water itself, the force of the currents it generates, the direct pressures exerted upon air and water imprisoned in crevices in the rock, the sudden expansion of air in crevices and pore spaces when the rapid retreat of a wave creates a partial vacuum outside, all these are described as effective causes of damage by waves, on the basis of concrete and seemingly reliable evidence. Our investigator must then have concluded that while shore debris is presumably a highly important factor in wave erosion, there is no reason to exclude the possibility that waves relatively free from debris, and striking with a force varying from hundreds to thousands of pounds per square foot, may accomplish much erosive work. He would therefore have rejected, not the hypothesis of storm-wave erosion, but his tentative deduction respecting the necessity of finding debris on the platforms; and would have looked for other deductions from the same hypothesis which he could use as a more reliable basis for testing its validity.

VI. Analysis in the Stage of Confirmation and Revision

From the fifth stage of the investigation the inquirer should emerge with a much depleted stock of working hypotheses. In some cases only one will remain as apparently competent to explain all the recorded facts. In other cases two or more may survive thus far. If but one, the cautious investigator will seek confirmation of its validity before utilizing it in his ultimate interpretation of the facts. If more than one, he pushes his studies further to discover which one represents the true explanation of the facts or whether they are jointly responsible for a complex result.

Whether one or several hypotheses survive the tests applied in the preceding stage, the survival is almost always in an "unfinished" state. The tests remain incomplete, and therefore inconclusive, because not all the desired facts are available, and perhaps not all the desirable deductions have been made. The investigator, let us imagine, has deduced five reasonable expectations from a certain hypothesis, of which three only are matched by facts in his possession. On the other hand, he has five categories of facts, of which three only correspond to expectations thus far deduced. He has two deductions having no counterpart in observed facts, and two groups of facts which are disturbing because not related to anything thus far deduced from the hypothesis. Just what these discrepancies mean, he does not know. They may mean that observation was incomplete and that new facts remain to be discovered. They may mean that deduction was incomplete or imperfect. In either of these two cases the hypothesis may be valid as it stands. But there are other possibilities. The discrepancies may mean that the hypothesis is invalid and must ultimately be rejected; or they may mean that it only requires a certain amount of revision to bring it into harmony with all the facts.

It is the task of the investigator in the stage of confirmation and revision to find out just what the discrepancies do mean. He searches for the missing facts which, if found, will constitute logical proof of the validity of the generalization involved in the hypothesis. Here the extraordinary value of the deductive processes of stage five becomes apparent. The observation of stage one was a wandering, unguided observation. But the renewed observation of stage six is skilfully directed observation. He now knows what to look for, and hence how and where to look. If, like the geologist or geographer, he is dealing with facts to be found in the field, directed observation will materially shorten his field work and greatly increase its fruitfulness. He goes directly to the places where the new facts should be found. If, like the physicist, chemist or modern student of biology, he must discover new facts through experimentation, skilfully directed experiment will replace the vague gropings of a less advanced stage of research. The deductive process has added new interest to the quest

for truth, and has enormously increased the probabilities of finding it.

Directed observation has another great value. It is apt to lead to the discovery of facts wholly unanticipated by the deductions which direct the search. As Davis has well said, the investigator's outsight on the facts is sharpened by his insight into the nature of his problem. Things which formerly made no impression on eye or mind now instantly arrest his attention, some because they are expected, but others for the very reason that they are quite unexpected. The discovery of facts that are wholly unanticipated, but which none the less find full explanation in a hypothesis under investigation, has exceptionally high value as confirmation of the hypothesis.

Where none of the deductions of stage five fully account for certain of the facts already in hand; or where newly discovered facts fail to find any counterpart in previous deductions; or, again, where some of the facts which should occur, according to a hypothesis otherwise well substantiated, can not be found, revision of the hypothesis is strongly indicated. Lack of completeness in deduction is especially apt to cause difficulty, and proper revision to include some new consequences not previously foreseen may bring complete harmony out of partial discord.

The process of securing the requisite confirmation, revision or rejection of hypotheses makes new and heavy demands upon the critical faculties. Especially is this true of the process of revision and rejection, which carries the investigator back over previous stages of the investigation in a search for some weak link in his chain of reasoning, some factor overlooked, or some item improperly included. If, as we have seen, analysis had a rôle to play in each of these preceding stages, how much more important is it that the analytical faculties should be on the alert in a review of one's reasoning in search for error. If previous work has been carefully performed, the error is not apt to be obvious. More likely it is obscurely involved in some apparently sound procedure, in which case it will continue to escape detection unless each bit of evidence, each argument and each conclusion are separated into their component parts and subjected to critical scrutiny. It is such analysis as this which must, in the circumstances detailed above, determine whether certain apparently incongruous facts should be rejected as irrelevant to the problem or included as fully pertinent; and in the latter case, whether a given hypothesis must be rejected or merely revised, before deduction and observation are brought into harmony.

VII. Analysis in the Stage of Interpretation

Let us suppose that the investigator has reached the seventh and final stage of his labors, in which he proceeds to formulate for publication his interpretation of the origin of shore platforms. Can he at last dispense with analysis, the instrument which has served him so well at every previous step in his labors?

Not wholly, I think. In any event there must remain with him a caution inspired by his full understanding of the nature of the proofs with which he is dealing, an understanding which comes only from critical analysis of both evidence and arguments. Rarely can geologist or geographer offer mathematical demonstration of the truth of his conclusions. He can, as a rule, go no further than to show that a given proposition has a high degree of probability. Certain facts carefully observed and properly classified prompt the invention of various hypotheses. The deduced consequences of one of these hypotheses alone is matched by all the facts, including some which are newly discovered and highly peculiar. The investigator therefore has much confidence that an interpretation based on this hypothesis will be valid. But he realizes there is still opportunity for error. He may not have thought of all possible hypotheses. He may not have deduced all the reasonable consequences of those hypotheses considered. He may not have discovered all pertinent facts. Some future contribution to knowledge may throw unexpected light on his problem and radically affect his conclusions. He therefore wisely regards his present interpretation as highly probable theory, rather than as demonstrated fact.

In previous stages an error led only one investigator astray, and that one could retrace his steps and repair damage by embarking on some new line of reasoning. But in this final stage an error committed to the printed page may lead many astray and may show wholly unexpected vitality and power for evil. The printed statements must go far enough; but they must not go farther than the evidence and fully tested reasoning warrant. A given interpretation must not be applied to all shore platforms before it has been completely demonstrated that there are no such platforms for which it is not the most satisfactory explanation. It must not even be asserted as the sole cause of any platforms, unless and until it has been clearly proven that no contributing cause has played a part in their formation.

In these and other ways the investigator must be on his guard against overstatement, understatement, erroneous statement of his results. Analysis is the weapon with which he defends himself against too broad generalization and other errors which are wont to intrude themselves into the final stage of an investigation. Each sentence he scrutinizes, each conclusion he dissects, checking here and verifying there, to the end that the formulation of his interpretation shall contain no less, and particularly no more, than

critically observed facts and carefully tested reasoning may justify. An interpretation thus cautiously reached and conservatively formulated will surely command the serious consideration of scientific men.

CONCLUSION

Have we, in the method of multiple working hypotheses, applied with the aid of rigorous analysis something which will guide us unfailingly to the discovery of truth? We are compelled to answer this question in the negative. No device, however perfect, can wholly deprive the human intellect of its capacity for making mistakes. De Leon searched in vain for the fountain of youth. Can we hope for a magical fountain of truth?

The most for which we may reasonably hope is by correct methods of research to reduce the chances of error to a minimum and to raise to its maximum the probability of discovering the real causes and relations of things. This we have done, so far as lies within our power, when we are accurate in observing facts, careful in classifying them, cautious in generalizing from them, fertile in inventing hypotheses, ingenious and impartial in testing their validity, skilful in securing their confirmation or revision and judicial in formulating ultimate interpretations.

Multiple working hypotheses as a method, employed in connection with critical analysis as an instrument of precision, offer us, in my opinion, the best guarantee of success in scientific research.

SCIENTIFIC EVENTS

UNIFICATION OF RADIO RESEARCH FACILITIES IN GREAT BRITAIN

THE facilities for radio research carried out by the British Department of Scientific and Industrial Research on the advice of their Radio Research Board have been improved by the unification of the Wireless Division of the National Physical Laboratory and the department's Radio Research Station at Slough into a new radio department of the National Physical Laboratory. Mr. R. A. Watson Watt, hitherto the superintendent of the Radio Research Station, is the superintendent of the new department.

Under the new arrangements the Radio Research Board continues to be appointed as at present by the lord president of the council, and its constitution and functions remain unchanged except that the opportunity has been taken to remove the anomaly by which the general work on the maintenance of radio standards at the National Physical Laboratory was a responsibility of the board. In the future the executive committee of the National Physical Laboratory will assume direct responsibility for these standards in the same way as it assumes responsibility for other national standards.

On the formation of the Radio Research Board in 1920, the National Physical Laboratory was entrusted with all work which required a laboratory equipped with instruments of the highest precision. Such work included the development of radio frequency standards, the study of problems of selectivity, aerial arrays and the generation of extremely short waves, as well as methods for the measurement of fundamental quantities necessary in accurate circuit design. Owing, however, to its situation and the proximity of other electrical work, the National Physical Laboratory was considered unsuitable for the conduct of radio research work requiring measurements in the field or on isolated sites. For work of this character facilities were provided by the department at the Radio Research Station erected on land adjoining the Admiralty Compass Observatory at Ditton Park, near Slough. Practically the whole work carried out on behalf of the Radio Research Board was thus divided between the Radio Research Station, Slough, and the National Physical Laboratory.

Although the Radio Research Station and the National Physical Laboratory have closely cooperated in the past, the unification which has taken place gives the Radio Research Board much greater freedom in planning its program as a single unit. The amalgamation of the staff of the two sections under a single direction is in the interests of efficiency and economy, and enables the increasing number of inquiries from industry to be made to one single establishment.

THE ANNUAL MEETING OF THE ROYAL INSTITUTION

THE annual meeting of the members of the Royal Institution was held on May 1, the president, Lord Eustace Percy, being in the chair. According to the report in *Nature* the annual report of visitors for the year ended December 31, 1932, testified to a year of considerable activity. The membership had been well maintained. The privilege of free attendance at the afternoon lectures by *bona-fide* students in London had been much appreciated and used. The report on the progress of the researches in the Davy Faraday Laboratory gave a good indication of the considerable extent of the research organization which is at work under the direction of Sir William Bragg. Some sixteen or eighteen workers are engaged, the majority on problems related to the x-ray determination of structure. Mention was made of Dr. J. M. Robertson's determination of the structure of anthracene, of Dr. A. Müller's work on the long-chain compounds, and of the growth in accuracy and capacity of the

large experimental x-ray plant in the hands of Dr. Müller and Mr. R. S. Clay. The capacity of the apparatus is calculated to be about 50 kw.; as yet it has worked well up to 10 kw. The treasurer's report and accounts showed a very satisfactory position, in spite of the heavy demand on the financial resources of the institution caused by the recent reconstruction. After a total expenditure in connection with the rebuilding of more than £100,000, a diminution in the invested funds of the Royal Institution of about £2,000 is shown. This gratifying result is a consequence of many generous donations to the Building and Research Endowment Fund raised by the institution in the past three years. The donations and other receipts to this fund have been sufficient to defray almost the entire cost of the rebuilding, and to go a considerable way towards completion of the program of permanent endowment of research which the managers of the institution have as one of their principal objects. The following officers for 1933–34 were elected: *President,* the Right Hon. Lord Eustace Percy; *Treasurer,* Sir Robert Robertson; *Secretary,* Major Charles E. S. Phillips.

NATIONAL RESEARCH FELLOWSHIPS IN THE BIOLOGICAL SCIENCES

THE annual meeting of the Board of National Research Fellowships in the Biological Sciences, for the award of 1933–34 appointments, was held in Washington on April 28 and 29, 1933. The board made twenty-six reappointments and forty-one new appointments, as follows:

REAPPOINTMENTS

For Domestic Study

Bond, R. M.—Zoology
Boughton, D. C.—Agriculture
Burkholder, P. R.—Botany
Casida, L. E.—Agriculture
Fry, Glenn A.—Psychology
Glass, H. B.—Zoology
Hopkins, E. W.—Agriculture
Jackson, T. A.—Psychology
Kelly, Isabel T.—Anthropology
Kerr, Thomas—Botany
Miller, E. S.—Botany
Morsh, J. E.—Psychology
Mowrer, O. H.—Psychology
Phelps, Austin—Zoology
Riley, H. P.—Botany
Shaw, Luther—Agriculture
Smelser, G. K.—Zoology
Smith, Wm. K.—Agriculture
Taylor, G. W.—Zoology
Tharp, Wm. H.—Botany
Wald, George—Zoology
Walls, Gordon L.—Zoology
Wolfe, J. B.—Psychology
Zirkle, R. E.—Botany

For Study Abroad

Hill, R. T.—Zoology
Sparrow, F. K.—Botany

NEW APPOINTMENTS

For Domestic Study

Abbe, Ernst C.—Botany
Barker, Horace A.—Zoology
Clark, Harold E.—Agriculture
Day, Harry G.—Zoology
Dyk, Walter—Anthropology
Edelman, Edward E.—Psychology
Gardner, Wm. U.—Agriculture
Goddard, David R.—Botany
Hamlett, Geo. W. D.—Zoology
Harrison, Carter M.—Agriculture
Hooker, Charles W.—Zoology
Hulse, Frederick S.—Anthropology
Hunt, Joseph McV.—Psychology
Jeffers, Katharine R.—Zoology
Krechevsky, Isadore—Psychology
Leeper, Robert W.—Psychology
Livingston, Luzern G.—Botany
Mackinney, Gordon—Botany
Misbach, L. E.—Psychology
Moyer, Laurence S.—Botany
Needham, J. G.—Psychology
Pady, Stuart M.—Botany
Park, Thomas—Zoology
Peckham, Robert H.—Psychology
Rosenfels, Richard S.—Botany
Rudnick, Dorothea—Zoology
Seltzer, Carl C.—Anthropology
Spence, Kenneth W.—Psychology
Steinbach, H. Burr—Zoology
Sumwalt, Margaret—Zoology
Williams, H. H.—Agriculture

For Study Abroad

Barron, Donald H.—Zoology
Baxter, Dow V.—Forestry
Birkeland, J. M.—Botany
Ehrlich, John—Forestry
Graham, Roy—Botany
Lindsley, D. B.—Psychology
Neatby, Kenneth W.—Agriculture
Snyder, Wm. C.—Agriculture
Wells, John W.—Zoology
Wilcox, A. N.—Agriculture

SUMMER CONFERENCE IN SPECTROSCOPY

ONE of the features of the summer research gathering of spectroscopists to be held at the Massachusetts Institute of Technology this year is to be a Spectroscopic Conference scheduled for the week of July 17–22. Each of the five days of the conference will be devoted to some particular branch of spectroscopy, the mornings being devoted to the presentation of papers and the holding of discussion groups, while the afternoons are to be left free

for informal discussions, laboratory inspections, and sight-seeing and recreation.

While the program is not yet complete, the following papers have already been scheduled:

Monday, July 17: *Quantitative Spectroscopic Analysis of Materials*

C. C. Nitchie, Bausch and Lomb Optical Company, "Some Practical Applications of the Spectrograph."

W. F. Meggers, Bureau of Standards, "The Physical Basis for Quantitative Spectrochemical Analysis."

F. Twyman, Adam Hilger, Ltd., "The Rôle of the Instrument Maker in Spectrum Analysis."

C. E. K. Mees, Eastman Kodak Company, "Photographic Plates for Spectroscopy."

Keivin Burns, Allegheny Observatory, leader of Discussion on Spectrochemical Analysis.

Tuesday, July 18: *Biological and Photochemical Applications of Spectroscopy*

W. A. Noyes, Jr., Brown University, "The Correlation of Research in Spectroscopy with that of Photochemistry."

P. A. Leighton, Stanford University, "Photochemistry and the Schumann Region."

F. Twyman, Adam Hilger, Ltd., "Basic Principles in the Design of Spectrophotometers."

G. B. Kistiakowsky, Harvard University, "Molecular Dissociation Energies from Spectroscopic Data."

Wednesday, July 19: *Physical and Astrophysical Aspects of Spectroscopy*

D. H. Menzel, Harvard University, "The Spectroscope in Astrophysics."

G. H. Dieke, The Johns Hopkins University, "Astigmatism of the Concave Grating."

F. H. Crawford, Harvard University, "The Present Status of Research on the Zeeman Effect in Molecular Spectra."

Thursday, July 20: *Analysis of Complex Spectra*

A. G. Shenstone, Princeton University, "Incompletely Analyzed Spectra."

W. F. Meggers, Bureau of Standards, "The Structure of Rare Earth Spectra."

G. H. Dieke, The Johns Hopkins University, "The Present Status of Wave-length Standards."

Keivin Burns, Allegheny Observatory, "Wave-length Standards."

Friday, July 21: *Spectroscopy and Atomic Structure*

(To be arranged), "Status of Theoretical Calculations of Atomic Energy States."

G. R. Harrison, Massachusetts Institute of Technology, "Status of Calculations of Spectral Line Intensities."

D. R. Hartree, University of Manchester, "Numerical Calculation of Atomic Properties."

J. C. Slater, Massachusetts Institute of Technology, "Analytical Calculations of Atomic Properties."

A number of other papers which have been tentatively scheduled are not listed because of uncertainties which had not been cleared up at the time of going to press. It is planned to follow each set of papers by extended discussion of the present status and future possibilities of each branch of spectroscopy considered.

PSYCHOLOGY AT CHICAGO

MEMBERS of Section I of the American Association for the Advancement of Science will meet in Chicago from June 20 to 23, in connection with the Century of Progress. Four psychologists from abroad will be present. Each of these will lead a symposium and in addition special lectures are scheduled. American psychologists will also participate in the symposia, the topics and leaders of which are as follows:

June 20, "Gestalt": Wolfgang Köhler, Berlin.

June 21, "Intelligence": Charles E. Spearman, London.

June 22, "Sensory Psychology": Henri Piéron, Paris.

June 23, "Character and Personality": Emilio Mira, Barcelona.

In addition to regular sessions the special symposia and lectures given in other sections of the association are of interest to psychologists. For example, the following may be mentioned:

June 20, forenoon, Dr. A. V. Hill, London, Symposium on Nerve Activity.

June 21, afternoon, Dr. R. Goldschmidt, Institute of Experimental Biology, Berlin, Symposium.

June 23, evening, Dr. C. U. A. Kappers, Brain Institute, Amsterdam, General Address.

The preliminary program follows:

Tuesday, June 20, 2:00 P. M. Symposium on Gestalt Psychology: Wolfgang Köhler, Berlin; R. H. Wheeler, University of Kansas; Heinrich Klüver, Institute for Juvenile Research.

Wednesday, June 21, 9:30 A. M. Symposium on Intelligence: Charles E. Spearman, University of London; Florence L. Goodenough, University of Minnesota. 11:30 A. M. Address: Henri Piéron, Paris.

Thursday, June 22, 9:30 A. M. Symposium on Sensory Psychology: Henri Piéron, Paris; Walter R. Miles, Yale University; Alvhh R. Lauer, Iowa State College. 11:30 A. M. Address: Emilio Mira, Barcelona.

Friday, June 23, 9:30 A. M. Symposium on Character and Personality: Emilio Mira, Barcelona; Mandel Sherman, University of Chicago; John E. Anderson, University of Minnesota.

Saturday, June 24, 8:00 P. M. General Address before the Association: Charles E. Spearman, University of London.

Dr. Walter R. Miles, of Yale University, is chairman of the section and Dr. John E. Anderson, of the University of Minnesota, is secretary. The meetings will be held in Thorne Hall and Lincoln Hall, McKinlock Campus, Northwestern University.

SCIENTIFIC NOTES AND NEWS

As has been fully reported in this journal, the American Association for the Advancement of Science and associated societies meet in Chicago from June 19 to 31. The Century of Progress Exposition has given the fundamental sciences the central place of honor, with the applied sciences radiating from it. The American Association and the societies devoted to the fundamental sciences will meet during the first week. These meetings will be followed by Engineering Week and the next week will be occupied by the National Education Association and its associated organizations. The full preliminary program of the meeting of the American Association and associated societies will be found in the issue of SCIENCE for May 19. The foreign scientific men who will take part in the meeting of the American Association as guests of the association and the Century of Progress Exposition are as follows: Dr. Otto Appel, of Berlin, agriculture; Dr. F. W. Aston, of Cambridge, chemistry; Dr. G. A. Bagge, of Stockholm, economics; Dr. Joseph Barcroft, of Cambridge, physiology; Dr. A. Mendelssohn Bartholdy, of Hamburg, political science; Dr. Jakob Bjerknes, of Bergen, meteorology; Dr. Niels Bohr, of Copenhagen, physics; Dr. Filippo Bottazzi, of Naples, physiology; Dr. Ludwig Diels, of Berlin, botany; Dr. Jean Dufrénoy, of France, agriculture; Dr. Leopold Fejér, of Budapest, mathematics; Dr. Enrico Fermi, of Rome, physics; Dr. A. P. M. Fleming, of Manchester, engineering; Dr. R. Goldschmidt, of Berlin, zoology; Dr. Herbert J. Gough, of London, engineering; Sir Daniel Hall, of London, agriculture; Dr. A. V. Hill, of London, physiology; Dr. C. U. A. Kappers, of Amsterdam, anthropology; Dr. Wolfgang Köhler, of Berlin, psychology; Dr. August Krogh, of Copenhagen, physiology; Dr. Tullio Levi-Civita, of Rome, mathematics; Dr. Emilio Mira, of Barcelona, psychology; Dr. William Oualid, of Paris, political economy; Dr. Henri Piéron, of Paris, psychology; Dr. J. J. Sederholm, of Helsingfors, geology; Dr. Charles E. Spearman, of London, psychology; Dr. The. Svedberg, of Upsala, chemistry, and Dr. R. J. Tillyard, of Australia, entomology and paleontology.

THE Royal Society, London, has elected as foreign members Professor Harvey Cushing, of the Harvard Medical School and the Peter Bent Brigham Hospital; Professor Peter Debye, director of the Institute of Physics at the University of Leipzig; Professor Friedrich August Ferdinand Christian Went, director of the Institute of Botany and of the Botanical Garden at the University of Utrecht, and Professor Vilhelm F. K. Bjerknes, professor of mechanics and mathematical physics at the University of Oslo.

DR. WILLEM DE SITTER, director of the Leiden Observatory, has been elected a correspondent of the French Academy of Sciences in the section for astronomy.

THE doctorate of science was conferred on Dr. William Morton Wheeler, professor of entomology at Harvard University, at the recent commencement exercises of Columbia University.

NEW YORK UNIVERSITY conferred at its commencement on June 1 an honorary doctorate on Dr. Florence Rena Sabin, member of the Rockefeller Institute for Medical Research.

THE University of Oxford will confer on June 21 the honorary degree of doctor of science on Dr. John Scott Haldane, fellow of New College and honorary professor and director of the mining research laboratory at the University of Birmingham.

THE original building of the New York State College of Forestry, which was opened in 1917, has been named in honor of Dr. William L. Bray, professor of botany and dean of the Graduate School of Syracuse University, who was the first head in 1911 of the College of Forestry. This designation was recommended by the faculty and authorized by the Board of Trustees of the College of Forestry on June 1. Since the early days of the college when he gave the first courses in forestry at Syracuse, Dean Bray has conducted courses in botany at the summer camp of the college on Cranberry Lake.

DR. OSWALD T. AVERY, of the Rockefeller Institute for Medical Research, has been elected president of the American Association of Pathologists and Bacteriologists.

LORD MELCHETT has been elected president of the British Science Guild, in succession to Sir Samuel Hoare, whose three-year term of office ends on June 19.

ACCORDING to *Nature*, Professor A. N. St. G. H. Burkitt, Challis professor of anatomy in the University of Sydney, has been elected president of the Linnean Society of New South Wales.

DR. EDGAR ALLEN, professor of anatomy and dean of the University of Missouri School of Medicine, will succeed Dr. Harry Burr Ferris as professor of anatomy and head of the department of anatomy at the Yale University School of Medicine.

DR. AUGUSTUS G. POHLMAN has resigned as research professor of anatomy and dean of the University of South Dakota School of Medicine to accept an appointment as professor and head of the depart-

ment of anatomy at Creighton University School of Medicine, Omaha, Nebraska.

PROFESSOR G. HADFIELD, professor of pathology in the University of London, has accepted an invitation to fill the chair of pathology at the University of Bristol to succeed Professor Walker Hall.

DR. A. K. KURTZ, formerly of the U. S. Civil Service Commission, has joined the staff of the Industrial Relations Division of the Procter and Gamble Company as statistician.

AMONG those who will work during the coming year in the School of Mathematics of the Institute for Advanced Study at Princeton are: Drs. A. A. Albert, University of Chicago; K. Gödel, University of Vienna; Jessen, University of Copenhagen; L. S. Pontrjagin, University of Moscow; Meyer Salkover, University of Cincinnati; T. Y. Thomas, Princeton University; E. R. van Kampen, Johns Hopkins University; R. L. Wilder, University of Michigan, and W. E. Bleick, Johns Hopkins University.

DR. RALPH W. CHANEY, head of the department of paleontology at the University of California, has left for northeastern Asia, where he will spend several months. He will return for the fall semester opening in August.

DR. J. BJERKNES, of the Geophysical Institute, Bergen, Norway, who is visiting the United States as the guest of the Century of Progress and the American Association for the Advancement of Science, addressed students of meteorology at the Massachusetts Institute of Technology and eastern Massachusetts members of the American Meteorological Society, June 9, on "The General Circulation of the Atmosphere." Several meteorologists took part in the discussion which followed.

SIR ALMROTH WRIGHT delivered the John Mallet Purser Lecture on "Immunization—the Old Doctrine and the New" at Trinity College, Dublin, on May 17.

THE first of a series of lectures, instituted by the British Science Guild for the purpose of directing attention to the importance of research—both purely scientific and technical—and the utilization of its results in the service of mankind, was given by Sir Harold Carpenter on May 16. The subject of the lecture was "Metals in the Service of Human Life and Industry."

DR. CHARLES F. BROOKS and Mr. S. P. Fergusson, of the Blue Hill Observatory, Harvard University, addressed the New Hampshire Academy of Science, at its annual meeting, June 3, on "Scientific Value of the Work of the Mt. Washington Observatory." Members of the academy drove up the mountain and inspected the observatory, which was established last fall following a grant from the academy. Mr. Fergusson will spend two months this summer on the summit, flying kites and captive balloons carrying recording instruments to show the effect of the mountain on the local wind velocity, temperature and humidity.

RECEIPT of a fund of $300 to pay for the first season of a new series of lectures at Northwestern University to be known as the U. S. Grant memorial lectures in honor of the late Professor U. S. Grant, who was head of the department of geology and geography, was recently announced by Dr. W. H. Haas, professor of geology and geography. The first lectures, probably next November, will be given by Dr. W. H. Collins, director of the Canadian Geological Survey. Dr. Collins has carried on work closely related to that of Professor Grant. The donor of the gift prefers to remain anonymous. It is a tribute from one scientific man to the memory of another. A gift of $150, also anonymous, for a scholarship to be known as the Grant graduate scholarship in geology and geography has also been announced.

THE annual initiation and banquet of the Michigan State College Chapter of the Society of the Sigma Xi was held at Michigan State College on June 1. Twenty-four new members were initiated. The public address was given by Dr. I. F. Huddleson on "Undulant Fever." The officers for the next academic year are: *President,* Dean R. C. Huston; *Vice-president,* Dean Marie Dye; *Secretary,* Professor V. G. Grove; *Treasurer,* Professor R. E. Marshall, who continues his office for another year.

THE Sigma Xi Club of Peking held its annual meeting and dinner on May 5. The speaker on the occasion was Dr. H. B. van Dyke, professor of pharmacology at the Peiping Union Medical College, who spoke on "Correlation among Glands of Internal Secretion." The officers elected for the coming year are: *President,* Dr. H. B. van Dyke; *Vice-president,* Dr. Toh Liu, dean of the College of Science, Normal University; *Secretary-treasurer,* Dr. Adam P. T. Sah, professor of physics, Tsing Hua University. The membership of the Sigma Xi Club in Peking has grown to over fifty. There is said to be evidence that the old capital, now called Peiping, is becoming increasingly important as a research center. Four universities, the Peiping Union Medical College (Rockefeller Foundation), the National Geological Survey and two research institutes are pursuing intensive scientific research programs. The local Sigma Xi membership, which is about one fourth American and three fourths Chinese, is distributed among these eight institutions.

DR. C. E. MCCLUNG, professor of zoology at the

University of Pennsylvania, and managing editor of the *Journal of Morphology,* who, as previously announced, is spending next year in Japan, requests that during his absence manuscripts for the *Journal,* until further notice, be sent directly to the Wistar Institute, Philadelphia.

THE South Carolina Legislature, in an act approved on May 13 and effective on that date, provided that "the property and duties of the State Food Research Laboratory at Charleston shall be associated with the State Medical College." The trustees of the Medical College have announced that, due to heavily reduced appropriations, it will be impossible to continue the laboratory, which has been engaged for some years on investigations in foods and nutrition. Present members of the laboratory staff are Drs. Roe E. Remington and Harold Levine, and Messrs. Harry von Kolnitz and F. Bartow Culp.

THE 150-foot ship that will carry Lincoln Ellsworth to the Antarctic is being prepared for its departure from Norway about the first of August for New Zealand. The ship is to leave New Zealand for the Bay of Wales about November 1, and will arrive at its base about December 15. The expedition is planning a 3,000 mile round trip non-stop flight over the Antarctic Continent.

THE California Institute of Technology has recently named a room in honor of Dr. Leon L. Watters, of New York. The room is in the Norman Bridge Laboratory of Physics and bears the following inscription: "The Watters Generator: The equipment in this room is the gift of Dr. Leon L. Watters, of New York, to the atomic structure research of the California Institute of Technology. It is designed to facilitate the generation of a steady potential of 300 KV, an energy available for x-rays ten times greater than any other equipment up to the present date." The apparatus will be employed to further the work begun by Dr. DuMond regarding which both Professor Einstein and Professor Millikan predict results of great importance.

THE Santa Barbara Museum of Natural History is building a children's loggia in memory of the former director, Ralph Hoffman. It is an addition to the east and south sides of the seismographic building, open in summer and glass-enclosed in winter, equipped with shelves and lockers and with water for modelling work. The design is by Carleton Winslow.

THE *Journal* of the American Medical Association states that negotiations for the organization of a school for public health nurses in Prague to be opened in 1934 have been completed. Construction is to start immediately. The preliminary education required for admission is to be graduation from a secondary school. Training in bedside nursing will be included in the two years course as well as a knowledge of social legislation applicable to field work. Half the cost of the construction of the school was promised to the Czechoslovakian government by the Rockefeller Foundation. The school will be erected on the grounds of the state institute of public hygiene in Prague. Bedside nursing will be practised in the near-by state hospital. Another feature of the school is that it will be for pupils both of the Czech and of the German language. The practical training in the field will be done for the Czech candidates in one of the demonstration districts of Prague, the one for German candidates in a demonstration district in northern Bohemia. The school will accommodate 100 pupils in its dormitory. It is hoped that it will create a type of field worker having the advantages of a trained nurse and at the same time knowledge necessary to understand social problems.

THE Institute of Medicine of Chicago offers a prize of $500 for the most meritorious investigation in medicine or in the specialties of medicine. The investigation may be also in the fundamental sciences, provided the work has a definite bearing on some medical problem. Competition is open to graduates of Chicago medical schools who have received the degree of M.D. during the year 1931 or thereafter. Manuscripts must be submitted to the secretary of the Institute of Medicine of Chicago, 122 South Michigan Boulevard, Chicago, not later than December 31, 1933. In the case of a paper submitted by more than one author, it is stipulated that all the authors must qualify, and that the prize paper be published under the same authorship as that under which it was submitted. The winner of the prize will be expected to present the results of his investigation before the institute at some meeting in 1934, the time to be designated later. If no paper presented is deemed worthy of the prize, the award may be withheld at the discretion of the Board of Governors.

DISCUSSION

THE PROBLEM OF TWISTED TREES

SURVEYING the various contributions to this subject, which have recently appeared in SCIENCE, the *Journal of Heredity, Journal of the New York Botanical Garden* and *Nature,* we find fair accord on the following essential points: (1) The wide distribution of

the regular tree twisting or spiral grain formation; (2) the aptitude of particular plant species to this structural form, and (3) the prevalence of tree twisting in certain localities. No agreement, however, is found as to the causes underlying this phenomenon.

Now, if we view the problem before us, in conjunction with such biological occurrences, as the curling and twisting of wool fibers, silk worm and spider's web, as well as the spiral growth of the bacterial colony filaments—we realize not only its general character but also that its solution is to be sought in the fundamentals underlying the evolution of organized matter.

Again, considering the fact that (1) the tracing of an organism's form and functions to some more primitive type of organic life is basic to our conception of evolution, (2) many fundamentals of organic life are but a reproduction of some characteristic property of the inorganic constituents (mineral medusa, mushroom and arboreal forms[1]) and (3) spiral formations are general throughout the inorganic world,[2] we may take it that the problem before us ultimately finds its foundation in the general principles of periodicity.[2]

Reviewing these principles, we find (I) periodic structures are the material record of an undulatory movement in a mobile magma. This movement characterizes generally the relationship of matter and energy and is expressible in terms of wave-mechanics. (II) as a record of change or transition periodic precipitations are determined by the relation existing between the frequency amplitude of undulation and the boundaries of the system and (III) periodic precipitations are in general not confined to physical or chemical phenomena only and are not restricted to any specific state or phase of matter or to any definite number of components.

In considering the problem of periodic precipitation, we must bear in mind, however, the fact that whilst the fundamental principles of periodicity and its material records are not limited to any state or phase, the actual type and complexity of each periodic precipitation is determined by all the properties of the particular phase of matter involved in the phenomenon. This is specially the case with the colloidal state capable of functioning as either a system-boundary, medium or component or even all these rolled together, thus evolving the mineralogical and biological periodic structures in all their ramifications.

Turning our attention to organized matter we find that minerals constitute an intrinsic component in every organic cell extending from the iron and sulfur bacteria up to the highest floral and faunal complexities.[3]

The alkaline earth group, together with some silicates, represents the material which imparts protection, rigidity and form to living matter. This function is the direct outcome of the physical and chemical properties of these substances, and therefore we may expect to find in the mineral world some primitive skeleton outline of the organic structural forms. Actually the salts of calcium, barium and strontium as well as silicates produce arboreal growth, such as creeper, bush and tree like forms.[1]

This stabilizing tendency—both in their inorganic condition and in organized matter—is undoubtedly due to the transitory colloidal state of these substances and the particular character of osmosis resulting from it. A more detailed study has shown that this characteristic is even more specific and the growth is typical to each individual radical or group.

So we find the calcium salts yield tree-like formations with a corrugated surface, barium salts give straight growth with a spiral surface, strontium salts form beautiful spirals, of a smooth tape-like growth, whilst silicates produce bamboo-like formations.

Again, our experience with the introduction of such groupings as sulfates, carbonates, phosphates and oxalates shows that the increase in constitutional complexity of the radical combinations, especially organometallic associations, is followed by a remarkable impetus in arboreal growth and general functional augmentation. Also, synthetic arboreal growth in the ferrocyanide, arsenate and arsenite groups finds probably a basic expression in the presence of hydrogen cyanide and arsenic in the organism, the assimilation of arsenates and arsenites by plants and the great therapeutic influence of arsenic on animals.

The gradual substitution of these substances by one another in the organism without impairing general metabolism seems to be well established. The silicious matter of the lower organism gave way to calcium carbonate, which in its turn was substituted by calcium phosphate in the higher forms. Our study of bacterial culture media, general nutrition and such plants as loco-weed, tobacco leaves, etc., shows that this substitution is applicable to barium and possibly strontium.

In the light of these facts it would seem that tree twisting is primarily due to local soil peculiarities which eventually modified the structural constituents of the plants. In the course of evolution the contact and inductive influences transformed the mineral efflorescence and arboreal growth into new structures more complex both in form and substance.

[1] Hatschek, *Proc. Roy. Soc.*, 95A: 303, 1919; Copisarow, *Jour. Chem. Soc.*, 233: 1927; *Koll. Zeits.*, 47: 60, 1929.

[2] Copisarow, *Koll. Zeits.*, 54: 257, 1931; *Jour. Phys. Chem.*, 36: 752, 1932.

[3] Copisarow, *Chemical News*, 134: 305, 323, 338, 1927.

The coming into being of organo-metallic and organic associations brought with it differences not only in composition but also in constitution resulting ultimately in the separation of optically active isomers by a process of gradual elimination.[4] The arboreal growth, retaining certain basic features of form inherent in their structural mineral radicles or groups, lost its arbitrary direction and became definitely orientated in accordance with the predominating stereo-isomeric form of its constituents.

The alteration in the direction of twist with age, recorded by several observers, is not really surprising. The great enzymatic transformation during embryonic development, ripening of fruit, as well as the intimate connection existing between enzymes and the cell nucleus—naturally involve a radical change in all plant constituents, which may of course be followed by a corresponding reversal of the helix.

Thus we find that the cause of the general twisting of trees is two-fold—internal and external. The internal factor is found in the specific character of the plant constituents (fusion products of heredity and environment) which determine the type of capillary spiral movement of its fluid nutrients and fibrillar depositions operating on the general principles of periodicity. In the case of young non-rigid plants these internal influences are enhanced or retarded (as the case may be) by light tropism and prevailing air currents. The systematic effect of these contributing external causes is however reduced to a minimum in old rigid formations.

Here, temperature, pressure, winds, sunlight as well as various parasitic and toxic influences may affect stature and produce structural abnormalities but do not participate in the evolution of the regular twisting in trees.

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CHLORPICRIN INJURIOUS TO GREENHOUSE PLANTS

IN view of the promising indications for chlorpicrin as a soil fumigant for nematode control, reported elsewhere,[1] recent evidence of the capacity of small concentrations of this gas in the air to injure greenhouse plants may be of special interest to investigators.

In an experimental fumigation of a plant bed just outside one of the Plant Pathology greenhouses at the University of California, Berkeley, California, some of the gas escaping from the soil found its way into the house and caused severe injury to tobacco, strawberry, coleus and other plants. The actual concentration of the gas as it became diffused into the greenhouse atmosphere was very low, probably not greater than 20 parts per million. It was detectable by a smarting of the eyes but not by odor. Details of the arrangement of the fumigated plot with relation to the greenhouse, together with illustrations and descriptions of the signs of injury produced upon the plants, will be presented in another paper, probably in *Phytopathology*. This preliminary statement is made as a warning to other investigators who may be contemplating making applications of chlorpicrin to greenhouse soils to control nematodes. If applications are made in benches or beds inside the house with growing plants elsewhere in the house, such plants may become severely injured from the escaping gas, even though they may be some distance away from the site of fumigation.

G. H. GODFREY

UNIVERSITY OF CALIFORNIA

THE ANNIVERSARY OF THE NORMAL CURVE

THE two hundredth anniversary of the discovery of the normal probability curve falls this year. It is interesting to note that the discovery of the curve was made by a man whose name is seldom, if ever, attached to it. It is also significant that the discoverer thought that his contribution was to pure or abstract mathematics and that the most practical use that could ever be made of his discovery was in connection with games of chance.

The man was DeMoivre. He published his findings on November 12, 1733. Since that time such wide use has been made of the curve that the above date becomes a landmark of considerable importance, especially in the social sciences.

In a recent book on the history of statistics[1] the following treatment of the event is found:

> The intensive study which DeMoivre gave to this work, together with his applications of the binomial theorem, led him a few years later—probably about 1721—to discover a formula for the ratio between the middle term and the sum of all the terms of $(1-1)^n$, and thus become the discoverer of the normal curve. Many of the recent treatises on probability and sampling approach the matter by a method quite similar to DeMoivre's use of the binomial expansion.
>
> This formula, first published November 12, 1733, is the *fons et origo* of the normal curve. In 1730 DeMoivre had brought out his *Miscellanea Analytica* and

[4] Mills, Brit. Assoc. Adv. Science, York meeting, 1932.

[1] M. O. Johnson and G. H. Godfrey, "Chloropicrin for Nematode Control." *Indust. and Eng. Chem.*, 24: 311–313. 1932. Other papers on this subject have been submitted for publication.

[1] Helen M. Walker, "Studies in the History of Statistical Method," pp. 13–14. Williams and Wilkins: Baltimore, 1929.

three years later he presented privately to a few friends a brief paper of seven pages with the title *Approximatio ad Summam Terminarum Binomii $a - b^n$ in Seriem Expansi.* The discovery of this exceedingly rare document is due to Pearson. . . .

In this obscure treatise on abstract mathematics, written in Latin nearly two centuries ago, and supposed by its author to have no practical implications outside the realm of games of chance, in this brief supplement now so rare that only two copies have been reported extant, we have the first formulation of the momentous concept of a law of errors.

CHARLES J. MARSH

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QUESTIONS

IF tomatoes grown in greenhouses have vitamins, does it mean that ordinary window-glass transmits ultra-violet radiations: or does it mean that plants can build up vitamins without the help of ultra-violet?

If sunlight is essential for chlorophyll formation by plants, how did it happen that sprouted seeds with primary and secondary roots, a stem and fully chlorophyllated cotyledons and primary leaves were found *inside* an opened Spanish succulent yellow gourd which had been in the shade in the house for eight months?

FREDERICK S. HAMMETT

PROVINCETOWN, MASS.

REPORTS

PUBLIC SERVICE AS AN ELEMENT IN THE LIFE OF THE AMERICAN SCIENTIST[1]

IT has been said truly, that our universities magnify the advantage of the individual at the expense of humanity. Few that leave academic halls with degrees in their pockets carry with them any considerable sense of public duty or think of anything beyond their own personal advancement. Recognition of the duty of parentage, for instance, is an essential element in any lasting civilization; but any sense of such a duty is almost entirely lacking among our collegiate young men and women. What professor in his lectures, what college president in his baccalaureate ever mentions that subject? Yet to teach and to practise public service, and service to humanity are especially the duties of scientific men.

Ours is the most humane and altruistic of professions. Yet we commonly fail, I believe, rather grievously in respect to public service. I shall deal with this subject quite concretely, as it is illustrated in a great social, political, moral and toxicological question now before the American people. I refer to the public duty resting upon American physiologists, biochemists, pharmacologists and pathologists in relation to the alcohol question.

Through an odd chain of events I became during the past year virtually, although of course unofficially, consulting toxicologist to the Congress of the United States. It is mainly on my advice that legal beer is to be 4 per cent. by volume and 3.2 by weight. The volume of such a beverage that must be taken to induce even the lowest slightly intoxicating concentration of alcohol in the blood (one milligram of alcohol per cubic centimeter of blood) is at the limit of the capacity of the human stomach.

The studies which this service involved led me to read practically all the testimony on this subject that has ever been given before Congressional Committees by scientific witnesses. And the more I read the more I was exasperated by the attitude that we scientists generally take when called on by legislators for advice; and the more tolerant and even sympathetic I become toward those much maligned bodies of men, the members of Congress and of the legislatures.

Legislators are necessarily called upon to decide a vast number of questions in all fields of human activity. On many of these questions even the most broadly educated man, unless he has specialized on that one subject, can have only superficial information. Legislators are not specialists. But they can and do call upon scientific men who have specialized on each particular question.

In this case the question is the toxicological properties of alcoholic beverages. What do they get in reply? One scientist says, "Alcohol is a food." Another says, "Alcohol is a powerful narcotic drug." Others add other facts. All these statements are true scientifically. But what is the poor legislator, anxious to do his duty and to legislate wisely, to make out of such raw facts? Scarcely any scientific witness seems to realize that what is actually needed is that he himself shall emphasize the practical significance of the scientific facts, and shall show the legislators to what conclusion and to what policy these facts point in relation to the public welfare.

I know that many scientific men will disagree with me on this. One of our most eminent colleagues, when I presented this view to him, offered the objection that what I proposed "involves more than the scientist's function; it requires him to speak as a citizen." To this I would reply that one does not escape the responsibilities of a citizen merely because he is a scientific expert.

As to the alcohol problem it is surely clear that the American people have made a woeful failure to control its evils both before and under prohibition;

[1] Part of an address at the dinner of the Federation of American Societies for Experimental Biology, at Cincinnati, April 11, 1933.

and that without scientific guidance a third experiment may not turn out any better. Is it not clear that this failure in the past, and possibly in the future, is due to the popular ignorance as to the underlying scientific facts? Is it not also true that it is only such scientific men as we who are gathered at this meeting that can supply and interpret the facts?

You may not believe it, but it is true, that a large, conscientious, determined and utterly ignorant element among our fellow citizens honestly believes that "beer is more intoxicating than distilled spirits." Not one legislator in a hundred realizes, until it is explained to him, that to allow spirits to be dispensed under the same conditions as the merely fermented beverages is equivalent to allowing tobacco shops to sell morphine and cocaine under the same conditions as tobacco.

Our British colleagues have served their nation much better. They have the great tradition and institution of royal commissions and similar advisory bodies that in England are so effective in the fundamental direction of national policy. On the alcohol question the facts and their meaning have certainly never been put more clearly than they were by a committee that reported a few years ago to the British Liquor Control Board. On that committee were such men as Cushny, Dale, Newman, Mott, McDougal and Sherrington. What they reported was virtually nothing more nor less than that the mass law of chemistry applies to alcoholic beverages. Those beverages that are concentrated are powerful and harmful in their effects. Those that are dilute are relatively innocuous. So clear was their report both in its presentation of facts and in the inference derived from those facts, that the Judiciary Committee of the Senate embodied the whole British statement in its own report.[2]

I have not the time in a mere after-dinner speech to develop this topic in detail. I have done so, however, in an article soon to appear in a general journal.[3] But is it not clear, when we face the facts known perfectly well to all of us here at this meeting, that the line of public policy and legislation that should be followed, that must be followed, if the evils of alcohol are to be minimized, is that of substituting the more dilute for the stronger alcoholic beverages?

I ask your cooperation in teaching the American people, and particularly the legislators, the mass law in its application to alcoholic beverages.

YANDELL HENDERSON

YALE UNIVERSITY

SCIENTIFIC APPARATUS AND LABORATORY METHODS

A LOW-COST LABORATORY UNIT FOR LIGHTING AND APPLIANCES

A LABORATORY table lighting unit has been designed for individual or class use to provide a satisfactory artificial light source for both high power microscopy and table or stage dissection, providing also outlets for electrical appliances. It is believed that the improvements incorporated will be of extended use where economy (*i.e.*, construction, installation charges and operation) must also be taken into consideration. The major points concerning the fixture are the utilization of the recently developed inside frosted blue daylight lamps in the larger sizes, suitable for use in naked fixtures without color filters or globes, and the convenience-outlets so often beyond reach but here made a part of the lighting fixture.

(1) Provision is made for interchangeable use of lamps from 150 to 300 watts, maintaining the center of illumination within the fixture by socket extensions for the 150 watt and 200 watt sizes, and employing the medium-screw "skirted" base for the largest size. Inside frosted Mazda blue daylight lamps are recommended for the reasons indicated in paragraph 3.

(2) Beam intensity values at the table top and 30 inches from the base of the unit, with the lower edge of the reflector hood 17 inches above the table top, for three sizes of inside frosted blue daylight lamps with same position of light-center, are as follows:[1]

Lamp size in watts	Socket extension	Intensity in ft. candles at 30° from plane of table[2]	Intensity in f-c in plane of table
150	3	23	9
200	2	30	13
300	0	41	16

(3) The quality of the light from the inside frosted blue daylight lamp matches average daylight suitably well for general use, and for those who are accustomed to studying by the latter medium this quality is an appreciable gain over the inside frosted white or the clear daylight incandescent lamps.

Normal lamp life is anticipated in the ordinary operation of the inside frosted blue daylight lamp in the fixture. It is pointed out, however, that the color

[2] Senate Report No. 1105, 72nd Congress.

[3] *Harper's Magazine* for June, 1933.

[1] Measured with Weston Model No. 603 Photronic Illumination meter, equipped with a green-yellow filter so that the color sensitivity of the instrument matched that of the human eye.

[2] Ca. angle of microscope mirror.

quality, intensity of the light and the life of the lamp are dependently related. For a closer approach to average daylight the lamps may be operated at from 100 to 105 per cent. of their rated voltage. When the average line-voltage during normal operation is 115 volts (*i.e.*, at full-load conditions of the circuit being used) lamps having a rated voltage of 110 volts may be used. This results in 60 per cent. of lamp life, 107 per cent. watts consumed, 116 per cent. light intensity and a color quality richer in the blue. The cost of operation (lamps plus energy) under these conditions is not an increase per unit of light, and permits the use of smaller bulbs for the same intensity and of a whiter light.

(4) The fixture-unit (see Fig. 1) has been sturdily

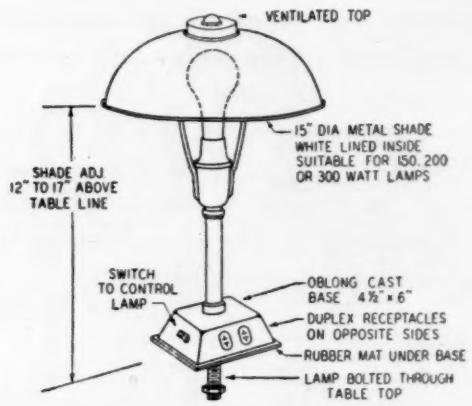

VENTILATED TOP
15" DIA METAL SHADE WHITE LINED INSIDE SUITABLE FOR 150. 200 OR 300 WATT LAMPS
SHADE ADJ 12" TO 17" ABOVE TABLE LINE
SWITCH TO CONTROL LAMP
OBLONG CAST BASE 4½" × 6"
DUPLEX RECEPTACLES ON OPPOSITE SIDES
RUBBER MAT UNDER BASE
LAMP BOLTED THROUGH TABLE TOP

FIG. 1

built. It is flexible in construction, with parts readily accessible. The height of the unit may be adapted so that the lower edge of the reflector hood is fixed at some arbitrary distance above the table top; *e.g.*, 12 inches for tables using one or two microscopes and up to 17 inches for tables using 6 microscopes. The reflector hood is ventilated to provide better lamp life. Its stem is intended to be rigidly connected to the table top to facilitate concealed table wiring; but this may be modified at a slight additional cost to permit surface wiring or use as a portable unit. A rubber guard is placed between the base of the unit and the table top to protect the wiring from liquids accidentally spilled around the base.

(5) The duplex receptacle outlets have been located in the lamp base convenient for simultaneous use of four electrical appliances, such as stage warmers, micro incineration outfits, etc. A separate toggle switch controlling the lamp only is also located in the base of the unit.

(6) Finish of the unit is made durable by a dull black bakelite coated surface; but may be altered to match other requirements. The interior (*i.e.*, reflecting) surface of the hood is a matte white having a coefficient of reflection of 94 per cent. in comparison with a standard magnesia test surface.

The reflector hood is proportioned and located to minimize direct glare from the unit itself and also from units on neighboring tables. The lamp proper is placed in the "base-down" position and only a portion of the neck of the lamp is visible. When the inside frosted blue daylight lamp is used, this visible neck portion of the lamp is free from objectionable glare.

(7) Low cost is obtained because of the simplified design, use of standard fittings and standard lamps. This low initial cost is accompanied by decreased wiring costs when making the installation because both the lighting and receptacle outlet loads are furnished from the same branch circuit, thus making it unnecessary to provide one complete branch circuit for the lighting and another complete branch circuit for the receptacle outlets. This unit may be installed in an existing laboratory without prohibitive rewiring costs.

Laboratory replacements are in progress using this new fixture at the Marine Biological Laboratory, Woods Hole, Massachusetts, with the cooperation of the Biddle-Gaumer Company, Philadelphia, and the laboratory facilities of the Moore School of Electrical Engineering, University of Pennsylvania.

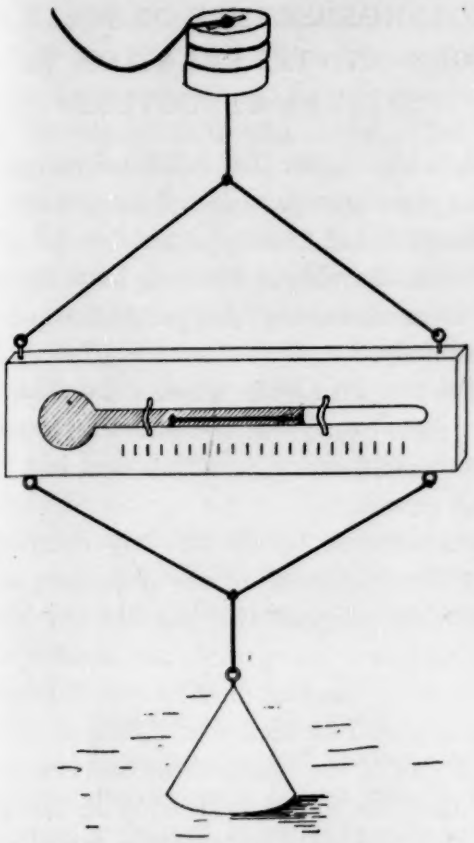
SAMUEL E. POND
OTTO MEIER, JR.
UNIVERSITY OF PENNSYLVANIA

A SIMPLE SUBSURFACE THERMOMETER

IN order that fishermen may take advantage of the findings of recent research into the relationship of fish to water temperature it is necessary that a subsurface thermometer be used in the course of fishing operations. The difficulty so far has been to devise an instrument of low cost. The apparatus described here entails only the purchase of an ordinary minimum thermometer. Since reversals of temperature gradient are comparatively rare, especially in water of less than 50 fathoms, the minimum thermometer can be used for practical purposes to give the temperature at the greatest depth to which it may be lowered.

The precaution necessary in its use is that it must be maintained in the horizontal position throughout the operation of lowering and hauling; otherwise the double-headed pin may slide. As a rule the pin is not very sensitive and will usually stand a tilt of as much as 30° without sliding. The accompanying illustration shows the means of maintaining the thermometer in the horizontal position.

It is suspended between the opposing pulls of a submerged float and a weight. The lifting power of the float is considerably less than the sinking power of the weight. The figure shows the apparatus resting on the sea-bottom, the usual position at which a temperature will need to be taken. The hauling



line is slack. Before lowering, the thermometer must be tilted so that the pin touches the meniscus. As the column contracts it is drawn back and left behind on subsequent expansion of the column as the thermometer reenters a zone of higher temperature. In the figure the size of the thermometer is exaggerated. In practice the distance from the thermometer to the sinker should be about a yard. On lowering, the bottom will be felt as in an ordinary sounding; and the observer has merely to wait a few minutes and haul up, the pull of the float maintaining the horizontal position throughout.

G. F. SLEGGS

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NEWFOUNDLAND

A SPECIMEN MOUNT FOR INSECTS AND OTHER OBJECTS OF NATURAL HISTORY, ETC.

THE following description of a method of making permanent mounts of natural history specimens is based on work done at the Bermuda Biological Station in January to March in 1933, the plan being adopted during January with trials of different manipulations and with tests of the availability of each.

A dry cell is made by punching the center of a cardboard, bristol-board or similar material of different thicknesses or, where necessary, by building up to desired thickness by assembling several together, and then gluing a proper sized sheet of Cellophane to one side with duco or Cellophane adhesive, making a cell of sufficient depth to accommodate the object to be preserved. The cell and the object are dried by warmth and then the cell closed by applying adhesive to the upper side of the card and drawing the Cellophane down over the cell and pressing it to make a smooth adhesion and, if desired, turning a lap over on the under side and closing the ends by laps of the Cellophane. This makes a mount that is completely enclosed by moisture-proof Cellophane protected from mold, moisture, insect pests or other sources of deterioration and is especially applicable for insect or other collections in tropical or humid climates. Specimens so mounted are available for immediate and convenient examination or study with lens or microscope, either compound or binocular, and can be studied from either side or even at a considerable angle, since the thin layer of Cellophane does not interfere with extremely close study. Records or labels placed on the cards before sealing are also permanently protected by the transparent covering. Specimens mounted in this manner during January and exposed for a number of weeks to the attacks of ants, cockroaches and other pests and also to molds have shown no traces of injury, and it is believed that they will maintain their condition for an indefinite period. Delicate insects like mosquitoes and parasitic hymenoptera as well as insects of larger size are kept in perfect condition.

These mounts have been observed by a number of workers at the Bermuda Biological Station and have also been shown to a number of other specialists and all have agreed that the method seems to have a wide application and to be worthy of special notice.

HERBERT OSBORN

OHIO STATE UNIVERSITY

SPECIAL ARTICLES

THE ABSOLUTE MOTION OF THE SOLAR SYSTEM AND THE ORBITAL MOTION OF THE EARTH DETERMINED BY THE ETHER-DRIFT EXPERIMENT[1]

THE ether-drift experiment, first suggested by Maxwell in 1876 and made possible by Michelson's invention of the interferometer in 1881, though capable of being applied to the detection of the general absolute motion in space of the earth, was actually arranged for detetcing only the known orbital component of the earth's motion. For the first time, in 1925 and 1926, at Mount Wilson, the writer made observations of such extent and completeness that they were sufficient

[1] Read before the National Academy of Sciences, Washington, D. C., April, 1933.

for the determination of the absolute motion of the earth. These observations involved the making of about 200,000 single readings of the position of the interference fringes, and lead to more than 25,000 single values of both the right ascension and declination of the apex of the motion.

The ether-drift effect in the interferometer, as is well known, is a second order effect, and the observations correctly define the line in which the absolute motion takes place, but they do not determine whether the motion in this line is positive or negative.

At the Kansas City meeting in December, 1925, before the completion of the Mount Wilson observations, a report was made showing that the experiment gives evidence of a cosmic motion of the solar system, but which failed to identify the effects of the orbital motion, though it seemed that the observations should have been quite sufficient for this purpose.[2]

In the autumn of 1932, a reanalysis of the problem was made, based upon the alternative possibility that the motion of the solar system is in the cosmic line previously determined, but is in the opposite direction, being directed southward. This gives wholly consistent results, leading for the first time to a definite quantitative determination of the absolute motion of the solar system, and to a positive detection of the effect of the motion of the earth in its orbit.

The apex of the cosmic motion of the solar system is located in the right ascension of 4 h., 56 m., and in declination 70° 30′ south, diametrically opposite the apex previously announced. The velocity of the cosmic motion is determined by comparison with the known velocity, 30 kilometers per second, of the earth's orbital motion, and has the value of 208 kilometers per second. For some unexplained reason the observed displacement of the interference fringes in the interferometer corresponds to about one twentieth of the full velocity. This might be accounted for by an incomplete Lorentz contraction, or by Stokes's theory of a dragged ether.

The location of this apex is in the southern constellation Dorado, the Sword-Fish, and is about 20° south of the star, Canopus, the second brightest star in the heavens. It is in the midst of the famous Great Magellanic Cloud of stars. The apex is only about 6° from the pole of the ecliptic; thus the indicated motion of the solar system is almost perpendicular to the plane of the ecliptic. This suggests that the solar system might be thought of as a dynamic disk which is being pulled through a resisting medium, and which therefore sets itself perpendicular to the line of motion.

DAYTON C. MILLER

CASE SCHOOL OF APPLIED SCIENCE

[2] SCIENCE, 63: 433–443, 1926.

THE PHOSPHORESCENCE OF SOLID NITROGEN AND ITS RELATION TO CRYSTAL STRUCTURE[1]

IN 1924 it was shown that solidified nitrogen, when exposed to electric rays, emitted an intense luminescence, consisting of bands, a number of which remained in the afterglow. Thus we have the case of a chemical element having the properties of a phosphorescent body.

When the temperature is raised above 35.5° K, solid nitrogen passes over from the phosphorescent α-form to another modification β, which has lost its phosphorescent power.

This phenomenon gives an important point of attack for the elucidation of the phosphorescent process. For this purpose the luminescent phenomena were analyzed and interpreted, and secondly the crystal structures of the two modifications of solid nitrogen were analyzed by means of Röntgen rays.

The analysis of the luminescent band-spectra led to the view that the bands appearing in the afterglow are due to "forbidden" electronic transitions from metastable molecular states. Thus the ε-system emitted from solid nitrogen corresponds to an electronic transition from the metastable A-state to the normal state of the nitrogen molecules.

The Röntgen-ray analysis gave for α-nitrogen a cubical structure, where the atoms of the molecular elements are arranged according to the space group T^4 and where the molecular axes have fixed positions in the space lattice. This structure lets us understand that the metastable states (which in the gaseous form are soon destroyed) in the α-form may be left undisturbed for a time sufficiently long for the forbidden transition to take place.

The analysis of the β-form was even more difficult, but finally it was found by us and independently by Ruheman that β-nitrogen has a hexagonal structure and that the elementary cell has dimensions nearly corresponding to a hexagonal closest packing of spheres.

For our problem it was of importance to go a step further and try to find out the positions of the individual atoms; but it appeared that the Röntgen reflections could only be accounted for by assuming the centers of the two atoms of a molecular element fall in the center of the molecules. This means that the individual atoms have no fixed positions and that the molecules rotate in the lattice. The rotating molecules require more space, which is seen from the fact that

[1] Read before the National Academy of Sciences, Washington, D. C., April, 1933.

the molecular volume by the transformation increases from 45.37 Å³ to 47.12 Å³. The rotating molecules also explain the rapid fall of the Röntgen-ray reflections with increasing deflection-angle. That molecular rotation can occur in the solid state is evident from the two modifications of hydrogen, and the problem has been theoretically treated by Paceling. In this connection, it is of interest to mention that the oxygen modification, stable above −229.5, was recently found by us to have a cubical lattice with rotating molecules. On the basis of our interpretation of the luminescence, we immediately see the reason why the β-modification has lost its phosphorescent power.

The rotational motions of the molecular elements of the lattice will disturb the metastable states just as in the gaseous system before the forbidden transitions can take place.

Reasons are given for the view that the excitation consists in a kind of dissociation process and that recombination takes place through certain metastable states. The phosphorescence, at any rate in our case, should be closely related to chemiluminescence, the main difference being that in the case of phosphorescence the reacting chemical substances are first to be formed through the excitation process.

L. VEGARD

COUPLED REACTIONS IN BIOLOGICAL SYSTEMS

THE following is a summary of some preliminary investigations of two coupled reactions in biological systems: (1) The reduction of pyruvate to lactate by means of the energy of the anaerobic oxidation of formate to bicarbonate, and (2) the reduction of fumarate to succinate through the anaerobic oxidation of lactate to pyruvate. Toluene treated *B. coli* served as enzyme system for both reactions.

It was found in both instances that an intermediate substance was necessary which could be reduced at the locus where the one metabolite was oxidized, and reoxidized where the other was reduced. The intermediate substances were methylene violet for the lactate-pyruvate-formate-bicarbonate system, and methylene blue for the succinate-fumarate-lactate-pyruvate system. Without these mediators no reaction occurred.

These findings support the hypothesis of active centers proposed by Quastel.[1] They indicate that "half reactions" can not occur, and therefore the necessity for mediators, or carriers of energy from the point where energy is liberated to the point where it is used, when the energy-liberating and energy-absorbing mechanisms are separate; *i.e.*, that in the toluene treated *B. coli* there is no mechanism corresponding to metallic conduction. They show also that toluene treated *B. coli* contain no mediators capable of serving in the two systems studied.

Further, these experiments suggest that when oxygen is used *in vivo* the centers at which oxygen is bound must be intimately associated with the dehydrogenase mechanisms, or that one or more mediators similar in their function to reversible dyes intervene between the oxygen binding and the dehydrogenase mechanisms. These alternatives are not mutually exclusive. They may co-exist and even supplement each other, as possibly, for example, in the case of the non-iron-containing respiratory ferment system described by Warburg and Christian.[2]

HERMANN F. SCHOTT
HENRY BORSOOK
CALIFORNIA INSTITUTE OF TECHNOLOGY

SOME ASPECTS OF INTERMEDIARY PROTEIN METABOLISM

THE exogenous origin of creatine was first demonstrated by Levene and Kristeller in 1909 in their protein feeding experiments with cases of muscular dystrophy. In 1929, we reported[1] that glycine fed to patients with muscular dystrophy produced a marked rise in creatine excretion (confirmed by Thomas *et al.*,[2] and others), whereas glutamic acid and cystine had no effect. Studies with a number of other amino acids and various other substances were also reported. The effect of the removal of glycine and of glutamic acid from the metabolic mixture through the feeding of benzoic acid and phenylacetic acid, respectively, was investigated. It was found that the former produced a marked drop in creatine, while the latter was without effect. We are inclined to infer from our experiments that the feeding of brombenzene, which removes cysteine from the metabolic mixture, would be without effect on creatine excretion. Owing to the possible toxicity of the substance we intend to carry out suitable animal experiments instead. The chart shows only the essential results of a few representative experiments.[3]

Hippuric acid, phenylacetyl glutamine and bromphenyl mercapturic acid formation: The finding that the feeding of benzoic acid and phenyl acetic acid in proper amounts may have no effect upon the total nitrogen catabolism, although there are appreciable amounts of glycine and glutamic acid, respectively, lost to the body as a result of "Abfang" processes,

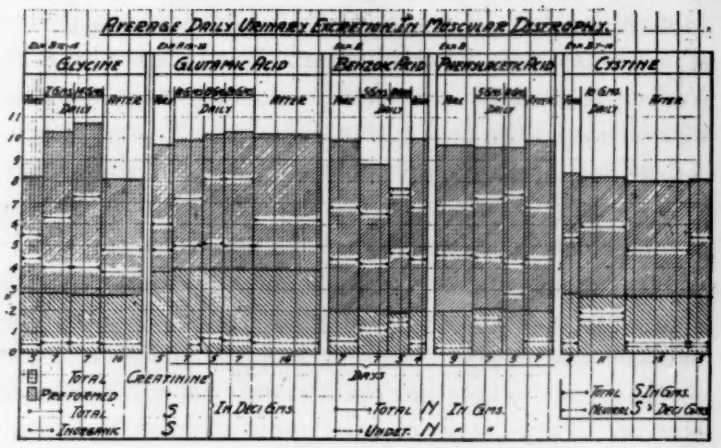
[1] J. H. Quastel, *Biochem. Jour.*, 20: 166, 1926.

[2] O. Warburg and W. Christian, *Biochem. Zeits.*, 258: 496, 1933.

[1] *Am. Jour. Physiol.* 90, 296.

[2] *Z. physiol. Chem.* 214, 121.

[3] The significance of our detailed nitrogen and sulfur studies can not be discussed here, due to lack of space.



we believe, would indicate that these amino acids are originally present in the metabolic mixture in appreciable amounts and not especially synthesized for detoxification. This view is substantiated by our findings that creatine is markedly reduced by the benzoic acid and uninfluenced by the phenyl acetic acid and also by our observations regarding the respective influence of glycine, glutamic acid and cystine upon the excretion of creatine.

The rôle of glutathione in intermediary protein metabolism: It is a surprising fact that the only three amino acids—glycine, glutamic acid and cysteine—which seem to be available for processes of detoxification in the human are the same as those which form glutathione.[4] If glutathione supplies the amino acids for these processes of detoxification, then the unaltered level of protein catabolism accompanying such processes would seem to indicate that an appreciable part of normal protein catabolism goes *via* glutathione. It is possible that this view may be further supported by the finding that methionine replaces cystine in cystine deficient diets (Jackson and Block) and by the observation regarding the influence of methionine on the detoxification of brombenzene in such diets (White and Lewis).

One may conceive that the substances, which are being detoxified, first combine with the glutathione, thereby rendering it more unstable, as a result of which the detoxified compound splits off in combination with part of the original glutathione molecule. This change in stability would be in keeping with our findings regarding factors which influence the lability of the glutathione and cystine molecules.[5]

E.g., phenylacetic acid would combine with the α-amino group of the glutamic acid radical of glutathione, following which the side chain splits off completely at the α-carbon of the cysteine liberating phenylacetylglutamine.

[4] This view has been expressed previously by others (Waelsch, H., *Arch. Exp. Path.* 156, 356; Power, F. W., Washington Meeting, Am. Chem. Soc. (1933)).

[5] *Jour. Biol. Chem.*, 70, 381.

Shiple and Sherwin have called attention to the obviously close relationship between phenylacetylglutamine excreted by man and phenylacetylornithine excreted by birds. Ornithine in this latter compound may be conceived as derived from glutathione by a process in which the distant carbonyl group of the glutamic acid radical is reduced to form a nor-valine radical, which if split off together with the α-amino group of the cysteine would yield ornithine. Such mechanisms may have some bearing on uric acid and pyrrole formation. The possibility of glutathione being a source of ornithine is of interest in connection with the work of Krebs on urea formation and the reported activation of arginase by glutathione. The glutamic acid linkage in glutathione, which linkage is not easily split by enzymes, has long been considered as unusual. The reactivity of the distant carbonyl group of the glutamic acid radical in glutathione hardly has been investigated.

Bromphenyl mercapturic acid referred to above contains an acetyl group, which may be a remnant of the glutamic acid radical of glutathione, rather than the result of acetylation.

Creatine formation: Our experiments indicate that the guanidine group of creatine is synthetic in origin and that glycine is involved in creatine formation. Since glutathione is now known to contain glycine, its possible relation to creatine formation is obvious.

Creatinine formation: Creatinester hydrochloride and related compounds spontaneously form their respective anhydrides upon neutralization, the free esters apparently being quite unstable (unpublished experiments by Failey and Brand). This behavior of creatinester might suggest that in the animal organism creatinine is formed from a creatine compound in which the carboxyl group of creatine is not free but linked up as an ester, thioxy ester or amide.

Our finding in cystinuria[6] regarding an unusual creatinine metabolism accompanying this disturbance in sulfur metabolism is of interest in this connection. Studies regarding the therapeutic and metabolic effects of glutathione and of mixtures of its constituent amino acids in myopathies are being planned.

We shall consider more fully some of the conceptions of protein metabolism outlined above and their implications in a more detailed publication of our experiments.

This work was aided in part by a grant from the Chemical Foundation.

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MEYER M. HARRIS

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[6] *Jour. Biol. Chem.*, 86, 315.